

# **INDOOR AIR QUALITY ASSESSMENT**

**Memorial Middle School  
502 Cabot Street  
Beverly, Massachusetts**



Prepared by:  
Massachusetts Department of Public Health  
Bureau of Environmental Health Assessment  
Emergency Response/Indoor Air Quality Program  
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## **Background/Introduction**

At the request of the Beverly School Department (BSD), the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) was asked to conduct an assessment of environmental conditions in the crawlspace at the Memorial Middle School (MMS), 502 Cabot Street, Beverly, MA. On June 3, 2003, a visit to conduct an indoor air quality assessment was made to this building by Cory Holmes, Environmental Analyst of BEHA's Emergency Response/Indoor Air Quality (ER/IAQ) Program. Mr. Holmes was accompanied by Ron Bouchard, Director of Facilities for the BSD. The assessment request stems from concerns of water penetration/microbial growth and poor ventilation within the crawlspace.

The MMS is a multi-story red brick building that appears to have been constructed in the 1950's. The top floor contains general classrooms, library and guidance counseling offices. The main floor contains general classrooms, an auditorium, office space and hallways that connect the main building to the gymnasium. The basement/ground floor is made up of science classrooms, cafeteria, computer/technology rooms, an art room and the unfinished crawlspace.

## **Methods**

BEHA staff performed visual inspection of building materials for water damage and/or microbial growth. Air tests for carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor, Model 8551.

## **Results**

The MMS houses students in grades 6-8. It has a student population of approximately 450 and a staff of approximately 50. Tests were taken under normal operating conditions. Test results appear in Table 1.

## **Discussion**

### **Ventilation**

It can be seen from Table 1 that carbon dioxide levels were elevated above 800 parts per million of air (ppm) in twelve out of seventeen areas surveyed, indicating inadequate ventilation in a number of areas throughout the school. During the assessment, the majority of ventilation systems were found deactivated. In addition, a number of classrooms had open windows or doors, which can greatly reduce carbon dioxide levels.

Fresh air in classrooms is supplied by a unit ventilator (univent) system (Picture 1). Univents draw air from outdoors through fresh air intakes located on the exterior walls of the building (Picture 2) and return air through air intakes located at the base of each unit ([Figure 1](#)). Fresh and return air are mixed, filtered, heated and provided to classrooms through a fresh air diffuser located in the top of the unit. As discussed, univents were found deactivated throughout the school. Obstructions to airflow, such as papers and books stored on univents and bookcases, carts and desks in front of univent returns were seen in a number of classrooms (Picture 3). In order for univents to provide fresh air as designed, intakes must remain free of obstructions and importantly, these units must remain activated and allowed to operate while these rooms are occupied.

Exhaust ventilation is provided by grilled, ducted vents located in ungrated holes at floor level (Picture 4). Exhaust vents are connected to motors in a rooftop penthouse (Picture 5). No draw from exhaust vents could be detected during the assessment. BEHA staff and Mr. Bouchard visited the rooftop penthouse and found all exhaust equipment deactivated. Without mechanical supply and exhaust ventilation operating, indoor air pollutants can build up and lead to indoor air quality/comfort complaints. Exhaust ventilation in both the boy's and girl's restrooms was also not operating during the assessment.

Mechanical ventilation in the gymnasium is provided by four ceiling-mounted air handling units (AHUs). Air is exhausted by wall-mounted grills. Neither the AHUs nor exhaust vents were operating during the assessment.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of occupancy. In order to have proper ventilation, the mechanical supply and exhaust systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. The date of the last balancing of these systems was not available at the time of the assessment. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994).

The Massachusetts Building Code requires that each room have minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week based on a time weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please refer to [Appendix I](#).

Temperature readings in occupied areas were measured in a range of 68° F to 75° F, which were slightly below the BEHA comfort guidelines in some areas during the assessment. The BEHA recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. However, it is more difficult to control temperature and maintain comfort without operating the ventilation equipment as designed (univents/exhaust vents deactivated).

The relative humidity readings in occupied areas of the building ranged from 28 to 47 percent, which were below the BEHA recommended comfort range in some areas. The BEHA

recommends that indoor air relative humidity is comfortable in a range of 40 to 60 percent. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

### **Microbial/Moisture Concerns**

As previously mentioned, the focus of this assessment was to examine conditions in the crawlspace. The crawlspace consists of cement foundation walls and a dirt floor. The height of the crawlspace is approximately ten feet. No mechanical means of ventilation exists in the crawlspace. A number of crawlspace vents that allow for air circulation (Pictures 6 & 7) were observed. Relative humidity levels in the crawlspace ranged from 78 to 83 percent, which was at least 31 percent higher than any occupied areas. Relative humidity in excess of 70 percent can provide an environment for mold and fungal growth (ASHRAE, 1989).

It appears that the crawlspace has been used for storage of discarded furniture and other classroom items for a number of years. Picture 8 depicts a severely water damaged wooden chair. Porous materials that can support mold growth (e.g. books, cardboard, paper and ceiling tiles) are stacked in piles on the crawlspace floor. Exposure to chronic moisture has resulted in mold growth on these items (Pictures 9 & 10).

BEHA staff observed several moisture sources causing water damage to materials stored in the crawlspace. Pooling water was observed in several crawlspace areas, possibly the result of raised water table levels. Furthermore, elevated relative humidity has resulted in condensation

formation in the crawlspace. When warm, moist air passes over a cooler surface (e.g. concrete foundation walls), condensation is formed and collects on the cold surface.

In addition to pooling water and elevated relative humidity leading to condensation in the crawlspace, several other potential sources of water penetration exist:

- Missing/damaged mortar around bricks and holes and spaces were observed in exterior walls (Pictures 11 & 12).
- Growth of small trees/stumps, and other plants in the tarmac/exterior wall junction (Picture 13) were seen along the perimeter of the building. The growth of roots/plants against the foundation/exterior walls of the building can bring moisture in contact with wall brick and eventually lead to cracks and/or fissures in the foundation below ground level.
- Missing/damaged gutters and downspouts were seen in several areas along the roof (Picture 14). Gutters and downspouts are designed to direct rainwater away from the base of the exterior walls. In some cases the gutter/downspout system empties water directly against the foundation. These conditions can undermine the integrity of the building envelope and provide a means of water entry into the building through foundation concrete and masonry by capillary action (Lstiburek & Brennan, 2001).

A number of areas had water-damaged ceiling tiles (Pictures 15 & 16), which is evidence of a roof or plumbing leak. In some cases damaged tiles have been directly adhered to the ceiling, which makes removal difficult. Water-damaged ceiling tiles can provide a source of mold growth and should be replaced after a water leak is discovered and repaired. Active leaks were reported in the cafeteria. Mr. Bouchard believed the leaks were most likely the result of

damaged flashing. Picture 17 shows an area on the exterior of the building where flashing is missing/damaged.

Finally, pooling water was observed on the roof outside of classroom 164 (Picture 18). Freezing and thawing of water during winter months can lead to roof leaks and subsequent water penetration to the building interior. Pooling water can also become stagnant, which can lead to unpleasant odors and microbial growth. In addition, stagnant pools of water can serve as a breeding ground for mosquitoes.

## **Conclusions/Recommendations**

In view of the findings at the time of the visit, the following recommendations are made to improve indoor air quality:

1. Seal utility holes and other potential pathways to eliminate pollutant paths of migration from the crawlspace to the first floor.
2. Remove any mold-contaminated materials (e.g. stored items) in the basement. Remove and replace (if necessary) any water damaged/mold colonized building materials. This measure will remove actively growing mold colonies that may be present. Remove mold contaminated materials in a manner consistent with recommendations found in Mold Remediation in Schools and Commercial Buildings published by the US Environmental Protection Agency (US EPA, 2001). Copies of this document can be downloaded from the US EPA website at: [http://www.epa.gov/iaq/molds/mold\\_remediation.html](http://www.epa.gov/iaq/molds/mold_remediation.html)
3. Consult with an architect and or general contractor regarding the integrity of the building envelope, primarily concerning water penetration through walls and the foundation. Examine the feasibility of repointing brickwork.

4. Consult an HVAC engineering firm to determine the feasibility of providing mechanical exhaust ventilation to the crawlspace. The crawlspace should be placed under slight negative pressure to prevent air penetration into occupied spaces.
5. Examine each univent for function. Survey classrooms for univent function to ascertain if an adequate air supply exists for each room. Consider consulting a heating, ventilation and air conditioning (HVAC) engineer concerning the calibration of univent fresh air control dampers throughout the school.
6. Ensure all operable ventilation systems (supply and exhaust) throughout the building (e.g. gym, auditorium, classrooms) are operating continuously during periods of school occupancy, independent of thermostat control. To increase airflow in classrooms, set univent controls to “high”.
7. Inspect exhaust motors and belts for proper function. Repair and replace as necessary.
8. Remove all blockages from univents and exhaust vents to ensure adequate airflow.
9. Ventilation industrial standards recommend that mechanical ventilation systems be balanced every five years (SMACNA, 1994). Consult a ventilation engineer concerning re-balancing of the ventilation systems.
10. Remove plants from the wall/tarmac junction around the perimeter of the building. Seal the wall/tarmac junction with an appropriate sealer.
11. Ensure all roof leaks are repaired. Repair/replace missing/damaged flashing along roof. Replace any remaining water-stained ceiling tiles (for dropped ceilings). Examine the areas above and around these tiles for mold growth. Disinfect areas of water leaks with an appropriate antimicrobial.

12. For removal of tiles directly adhered to the ceiling, such removal would be considered a renovation activity that can release particulates and spores in particular, if the material is moldy. Replacement of ceiling tiles may involve glues that contain VOCs. In order to minimize occupant exposure, repairs should be done while the building is unoccupied.
13. Reinstall missing downspout in Picture 14 to direct rainwater away from the foundation.
14. Consult with a roofing contractor to prevent water pooling on roof shown in Picture 18.
15. Consider adopting, the US EPA (2000) document, Tools for Schools, in order to provide self assessment and maintain a good indoor air quality environment at your building. The document can be downloaded from the Internet at <http://www.epa.gov/iaq/schools/index.html>.
16. For further building-wide evaluations and advice on maintaining public buildings, see the resource manual and other related indoor air quality documents located on the MDPH's website at <http://www.state.ma.us/dph/beha/iaq/iaqhome.htm>.

## References

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[http://www.epa.gov/iaq/molds/mold\\_remediation.html](http://www.epa.gov/iaq/molds/mold_remediation.html)

**Picture 1**



**Typical Classroom Univent**

**Picture 2**



**Univent Fresh Air Intake**

**Picture 3**



**Univent Airflow Obstructed by Various Items**

**Picture 4**



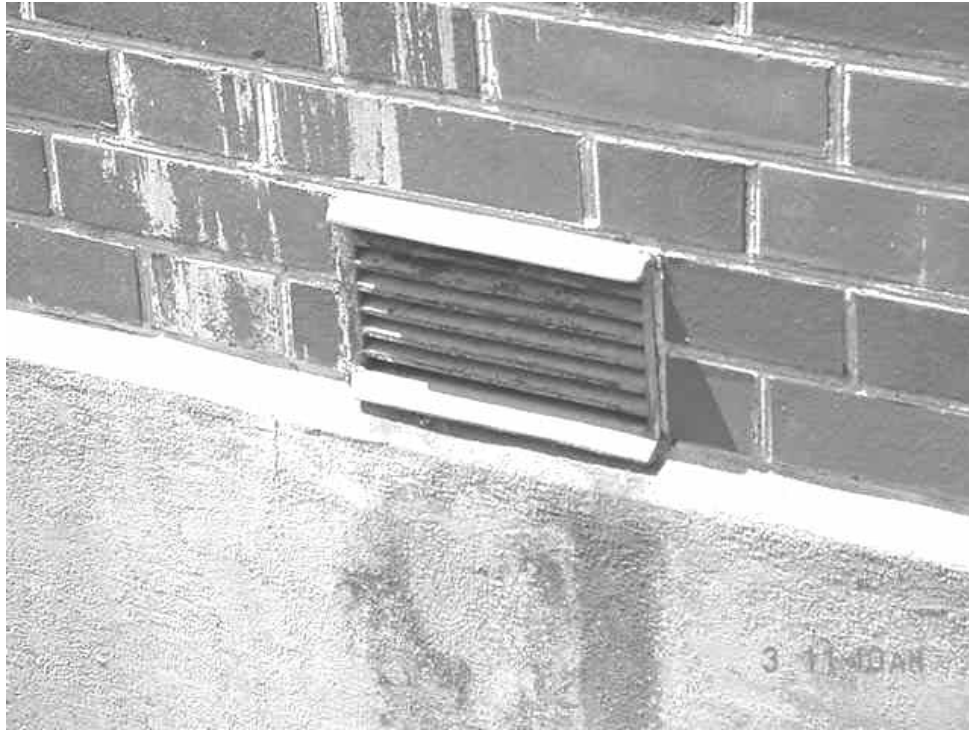
**Exhaust Cubby at Floor Level Used as Storage**

**Picture 5**



**Rooftop Penthouse for Ventilation Equipment**

**Picture 6**



**Passive Vent for Crawlspace**

**Picture 7**



**Passive Vent for Crawlspace, Interior View Note no Mechanical Components**

**Picture 8**



**Chair Leg Disintegrated from Moisture Exposure, Dark Material on Ground is Remnants of Chair Leg/White Material is Mold Growth**

**Picture 9**



**Cardboard Boxes Colonized by Mold in Crawlspace**

**Picture 10**



**Cardboard Boxes Colonized by Mold in Crawlspace**

**Picture 11**



**Missing/Damaged Mortar in Exterior Brick**

**Picture 12**



**Cracked/Damaged Foundation**

**Picture 13**



**Shrubbery/Plants Against Building**

**Picture 14**



**Missing Downspout**

**Picture 15**



**Water Damaged Ceiling Tiles along Window Frame in Classroom**

**Picture 16**



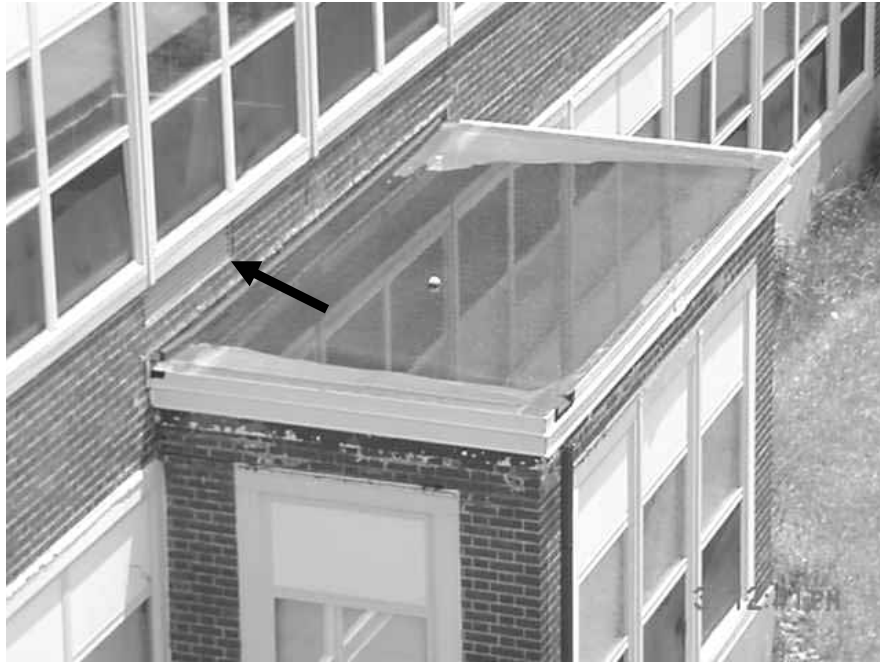
**Water Damaged Ceiling/Wall Tiles in Auditorium**

**Picture 17**



**Missing/Damaged Flashing along Roof**

**Picture 18**



**Pooling Water on Roof Outside Classroom 164, Note Univent Air Intake**

**TABLE 1**  
**Indoor Air Test Results – Memorial Middle School, Beverly, MA**

**June 3, 2003**

Location	Carbon Dioxide (*ppm)	Temp. (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Supply	Exhaust	
Outside (Background)	370	72	27					Clear, warm, sunshine Light breeze
Crawlspace	501	67	84					Small passive vents, pools of water, mold growth on paper/cardboard items
Mechanical Room	518	67	84	0	N	Y	N	
Perimeter Outside								Missing down spout, cracks in brick/foundation, missing flashing along roof (front)
Room 15	1574	71	41	13	Y	N	N	Space under door Old wooden doors
Music Room 134	1005	70	44	2	Y	Y	Y	Exhaust blocked-piano
Room 145	820	72	39	0	Y	Y	Y	No draw exhaust
1 <sup>st</sup> Floor Boys Room	632	71	30	4	Y	N	Y	Exhaust not operating
Room 150	1040	72	34	15	Y	Y	Y	Supply and exhaust off, plants, CT along window, door open, UV obstructed by desk

\* ppm = parts per million parts of air  
WD-CT = Water damaged ceiling tile

**Comfort Guidelines**

Carbon Dioxide -	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

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Location	Carbon Dioxide (*ppm)	Temp. (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Supply	Exhaust	
Room 156	580	73	32	15	Y	Y	Y	Door and windows open
Room 151	1589	73	39	20	Y	Y	Y	Exhaust cubby used for storage
Room 216	946	74	34	20	Y	Y	N	Window open
Room 214	2406	74	46	21	Y	Y	Y	
Library	862	74	32	20	Y	Y	Y	Plants, windows open Cubbies used for storage
Room 219	821	75	34	16	Y	Y	Y	Door and window open Heat issues in winter
Roof Top								All exhaust equipment located in penthouse-deactivated, water pooling on small roof – air intake, periodic roof leads – flushing (cafeteria)
Room 221	871	73	35	0	Y	Y	Y	Window open
Room 226	414	72	28	0	Y	Y	Y	Window open

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						Supply	Exhaust	
Room 202	540	74	30	0	Y	Y	Y	Window open, UV – on (weak) Filter clogged
Room 164	1517	73	31	17	Y	Y	Y	Standing water on roof outside UV
Gym				~50	N	Y	Y	Vent off, 4 CT, reports of back draft from vents
Boys Locker Room	571	68	33	0	Y	Y	Y	Showers seldom used Vent off
Girls Locker Room	468	68	30	0	Y	Y	Y	Vent off Showers seldom used
Auditorium	870	70	47	32	Y	Y	Y	Historic WD – wall/ceiling tiles & plaster, vent not operating, used as class room daily

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